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THE EFFECT OF STORAGE ON COLOR AND SPROUTING OF RED McCLURE POTATOES AFTER 2,4-D TREATMENT[1]

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Recently it has been shown that it is possible to intensify significantly the red skin color and to increase the vitamin C content of Red McClure potatoes, without depression in yield, by treating plants prior to harvest with small amounts of the sodium salt of 2,4-D (6). In view of the value to the potato industry, particularly to the growers in the San Luis Valley of southern Colorado, it is important to know whether the intensified red skin color remains during storage and what effect treatment has on sprouting and growth during the next growing season.

The objectives of this paper have been to obtain definite data to answer these questions.

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Review of Literature

Loss of Color in Storage

The amount of loss of color in storage of Red McClure potatoes has been reported by Kunkel (9). Untreated controls during the 1947-1948 storage season lost 6.78 per cent of their original color. Potatoes from various fertilizer plots showed an average loss of 7.58 per cent, and those from various minor element plots revealed an average color loss of 3.08 per cent. All tubers were grown and stored at the San Luis Valley Experimental and Demonstration Farm near Monte Vista, Colorado.

Inhibition of Sprouting by Hormones

Much work has been done on the problem of inhibiting sprouting in potatoes by chemical means. The bulk of this work was done at Boyce Thompson Institute by Guthrie (7), Denny and co-workers (3,4,5.) A brief review of the work conducted on field and storage application of sprout inhibitors was reported recently by Fults *et al.* (6). More recently Marshall and Smith (10) found that sprout inhibitors show different degrees of activity in storage depending upon the methods of application. Marth and Schultz (11) reported that sprouting and late blight development on potato waste piles could be prevented if the cull potatoes were given dormancy treatments before and after being placed on the cull piles.

Daines and Campbell (2) reported that tubers to be used as seed should not be treated with the methyl ester of alpha-naphthaleneacetic acid.

Brown (1) found that the addition of Folosan (containing 20 per cent pentachloronitrobenzene) markedly reduced the sprouting of tubers and protected the sprouts from damage by *Rhizoctonia solani,* yet, it did not affect the yield of the succeeding crop (6).

The Influence of Sprouts on Emergence, Number of Stems, Tubers, and Yields

McCubbin (12) studied the influence of sprouts on plant emergence. He found "sprouted seed" produced plants above ground earlier than "desprouted seed". The largest *number of stems* per plant was produced by potatoes desprouted prior to planting. The largest *number of tubers* per plant was produced by plants having the largest *number of stems.* The data indicated that the final yield in weight of tubers from sprouted, desprouted, and dormant seed would depend primarily on time of planting, length of growing season, and climatic conditions.

Methods and Materials

Source of Materials

The potatoes used were grown at the San Luis Valley Experimental and Demonstration Farm near Monte Vista, Colorado in 1949. Two lots were studied. *The first lot,* hereafter referred to as "replicated plot samples", consisted of five control samples and five treated samples selected from

Experiment No. 1 of the field plot described in (6). The five treated samples received one pound per acre of the sodium salt of 2,4-D applied once as a basal plant spray at the time the tubers were ¾ inch in diameter. *The second lot,* hereafter referred to as "field test samples", consisted of one control sample and one treated sample selected from Experiment No. 3 as described in (6). The treated sample received ⅓ pound per acre of the sodium salt of 2,4-D, applied once as a basal plant spray at the time the tubers were ¾ inches in diameter. Control lots received no 2,4-D treatment. All plots were sprayed with DDT for psyllid control.

Storage Conditions

All samples were stored in slatted oak crates, size 16 in. x 16 in. x 20 in. At the start of the storage period each crate contained 100 tubers, all of which were 1⅞ inches in diameter or larger. Within each lot the crates were stacked in a random manner. All samples were stored in the potato cellar of the Horticultural Department, Colorado A. and M. College at Fort Collins, Colorado. The temperatures in this cellar averaged 40°F during most of the storage season. Temperatures were slightly higher during the first sixty days.

All samples were harvested on September 19th, 1949. The replicated plot samples were placed in storage on October 5th, 1949, and kept in storage until May 15th, 1950. On October 5th, November 5th, December 5th, and March 5th samples were removed for determination of skin color. The sprouting data were recorded on May 15th. Field test samples were placed in storage on September 24th and removed on May 25th. Samples were then taken for the determination of skin color on September 24th and March 24th, and for sprouting studies on May 25th.

Methods of Sampling

The selection of all samples for our studies was made at random. At each sampling date, for the replicated plot samples, 50 control potatoes and 50 treated potatoes were used. These were selected from the five crates of controls and the five crates of treated potatoes. Ten potatoes of uniform size were selected from each crate. Determinations were on an individual potato basis.

At each sampling date for the field test, twenty uniformly sized potatoes from the control plot and twenty from the treated were measured for skin color. Ten determinations were made on each potato, or a total of 200 for each treatment.

At the end of storage, when sprout data were obtained, 50 tubers were selected from each crate in the "replicated plot samples", or a total of 250 control and 250 treated potatoes. One hundred tubers were selected from the control and from the treated "field test samples." The weight of sprouts per tuber in grams and the number of sprouts per tuber were

used as criteria of effects on sprouting. The tuber weights were also recorded.

Method of Measuring Red Skin Color

The Schaar Photoelectric Reflectometer Model 610, described in a previous paper (6), was used to determine differences in red skin color. All measurements were made directly on uninjured potatoes.

Location of Second Year Test Plots

Test plots to determine the effect of treatment on subsequent yield, stems per plant, stands, and growth were located on the Fred Falk farm near Del Norte, Colorado.

Results

Loss of Color in Storage

For the direct measurement of red skin color of the *replicated plot samples* at the four sampling dates — October 5th, November 5th, December 5th, and March 5th — the Schaar Photoelectric Reflection Meter Model 610 (6) was used. Five readings on the surface of each of ten potatoes, selected for size and uniformity from each of the five treated and the five untreated plots, were recorded. The mean galvanometric readings for these samples at the four dates are included in table 1. The galvanometric units are a measure of "apparent luminous reflectance" or "lightness" — the darker the red color, the lower the reading. The amount necessary for significance (Table 1) shows that the treated potatoes were significantly darker red than the untreated at all dates with the exception of one. Both the treated and untreated samples lost color during storage.

The variance analyses (Table 1) show that the ratio (9.70) of the variability between potatoes to that within potatoes is so large that unquestionably some of the difference in color must be due to the potatoes themselves. Inasmuch as the same potatoes could not be used throughout a study of this type, this variability could not be removed. However, again the analyses show that a large amount of the variability is due to the treatment, which indicates that the treated potatoes were significantly darker red than the untreated.

The mean galvanometric readings for the Field Test samples at the two dates are shown in table 2. Here again the treated samples were significantly darker red than the control at both dates. Although both the treated and the untreated samples lost color during storage, the treated were still darker red than the untreated. Variance analyses of the data were made in a manner like that shown in table 1, with similar results.

Effect of Treatment on Weight and Number of Sprouts

The weights of the sprouts on each of the 250 potatoes selected from the replicated treated samples and also those on the 250 from the control samples were recorded together with the weights of the tubers.

TABLE 1—*The effect of date of sampling and 2,4-D treatment on the skin color of Red McClure potatoes during storage. Replicated plot samples.*

GROUP COMPARISONS

Dates	Mean Galvanometric Readings		Difference
	2,4-D Treated	Controls	
October 5	40.74 1)	44.99	—4.25
November 5	42.98	42.52	0.46
December 5	41.81	44.95	—3.14
March 5	44.52	47.56	—3.04

Standard deviation = 1.82 Standard error = 2.32

In comparing the dates within treatments or treatments within dates, the same criteria would be used.

Minimum difference required for significance at the .05 level = 0.84
Minimum difference required for significance at the .01 level = 1.11

VARIANCE ANALYSES

Variability due to	D/F	Sums of Squares	Mean Squares	Obs. F	Required F	
					.05	.01
Totals	399	3461.1				
Between treatments	1	621.5	621.5	88.11	3.86	6.70
Within treatments	(398)	2839.6	7.1			
Between dates within treatments	6	1030.1	171.7	37.19	2.12	2.85
Within dates within treatments	(392)	1809.5	4.6			
Between potatoes within dates within treatments	32	837.8	26.2	9.70	1.48	1.72
Within potatoes within dates within treatments	(360)	971.6	2.7			
Totals	399	3461.1				
Between dates	3	716.7	238.9	34.47	3.86	6.70
Within dates	(396)	2744.4	6.9			
Between treatments within dates	4	934.9	233.7	50.64	2.12	2.85
Within treatments within dates	(392)	1809.5	4.6			
Between potatoes within treatments within dates	32	837.8	26.2	9.70	1.48	1.72
Within potatoes within treatments within dates	(360)	971.6	2.7			

1) These are galvanometer units read on a Schaar Photoelectric Reflection meter, Model 610, and are a measure of "apparent luminous reflectance" or "lightness". A standard polished white porcelain surface produced a galvanometer reading of 80. The **darker red** the color the **lower** the readings.

A green tristimulus filter in the search unit was used.

TABLE 2—*The effect of date of sampling and 2,4-D treatment on the skin color of Red McClure potatoes during storage. Field test samples.*

GROUP COMPARISONS

Dates	Mean Galvanometric Readings		Difference
	2,4-D treated	Control	
September 24	41.00	43.05	—2.05
March 24	42.92	44.34	—1.42

Standard deviation = 1.68 Standard error = 2.37
Minimum difference required for significance at the .05 level = 0.42
Minimum difference required for significance at the .01 level = 0.55

In order to remove that portion of the variability in the sprouts which might have been due to the weight of the potatoes, a co-variance analysis was used. The method in the past for removing potato weight variability, in cases such as this, has been to change the sprout weight to grams per 100 grams of tuber. The co-variance analysis, by the use of adjusted sums of squares, is a better procedure for removing original potato weight variability (8), and gives the more reliable ratio. This "F" value (181.94) shows that the controls had very significantly heavier sprouts than the treated potatoes.

The "r" values in table 3 show that the data for the weight of the sprouts correlate well with the data for the weight of the potatoes, thus indicating a tendency for heavier sprouts to occur on heavier potatoes. The greater part of the original potato weight data falls within the limits shown by 129.0 ± 39.2 grams, and most of the original weights of the sprouts lie within the range 1.4 ± 0.7 grams.

Co-variance analyses were used in studying the weight and number of sprouts per tuber in the *field test samples.* Table 4 shows that the weight of the sprouts in the control samples was significantly greater than the weight of the sprouts in the treated samples, and table 5 indicates that the treated had a significantly *larger number* of sprouts than the control potatoes. The "r" values in both tables revealed that the data were well correlated in field test samples. The greater part of the original potato weight data falls within the limits shown by 121.1 ± 50.5 grams and most of the original weights of the sprouts lie within the range 2.5 ± 1.1 grams. The range for the number of sprouts per tuber was 4.9 ± 1.8.

Potatoes from the replicated plot samples were desprouted May 15th, 1950 and planted at Del Norte on the 18th. The number of stems emerging per plant was counted on July 9th. An analysis of variance indicated no significant differences between the number of stems per plant or the stands in the control and treated potatoes.

TABLE 3—*Analysis of covariance of the effect of 2,4-D treatment on the weight of sprouts in grams per tuber (y) and the tuber weight in grams (x) in Red McClure potatoes. Replicated plot samples.*

Variability due to	D/F	Sums of Squares and Products			x Obs. F	Variance Analyses Req. F		y Obs. F
		x^2	xy	y^2		.05	.01	
Totals	499	846188.2	9911.6	452.7				
Between treatments	1	36385.6	2198.3	132.8	22.38	3.86	6.69	206.80
Within treatments	(498)	809802.7	7713.3	319.8				
Between plots within treatments	8	58295.3	1356.8	59.6	4.75	1.96	2.55	14.04
Within plots within treatments	(490)	751507.3	6356.4	260.2				

Variability due to	D/F	Adjusted Sums of Squares		Obs. F	Req. F		r
		Sums of Squares	Mean Squares		.05	.01	
Totals	498	336.6					+0.506
Between treatments	1	90.2	90.2	181.94	3.86	6.69	
Within treatments	(497)	246.4	0.5				+0.479
Between plots within treatments	8	39.9	5.0	11.83	1.96	2.55	+0.728
Within plots within treatments	(489)	206.4	0.4				+0.455

Adjusted mean for the weight of sprouts per tuber control = 1.83; and for treated = 0.96, with a difference of 0.87.

Minimum difference required for significance between adjusted means of weights of sprouts at .05 level = 0.12; and at .01 level = 0.16.

TABLE 4—*Analysis of covariance of the effect of 2,4-D treatment on the weight of sprouts in grams per tuber (y) and the tuber weight in grams (x) in Red McClure potatoes. Field test samples.*

Variability due to	D/F	Sums of Squares and Products			Variance Analyses			
		x^2	xy	y^2	x Obs. F	Req. F .05	Req. F .01	y Obs. F
Totals	199	611372.6	5030.1	259.0				
Between treatments	1	107193.8	—1502.5	21.1	42.10	3.89	6.76	17.53
Within treatments	(198)	504178.8	6532.6	237.9				

Variability due to	D/F	Adjusted Sums of Squares		Obs. F	Reg. F		r
		Sums of Squares	Mean Squares		.05	.01	
Totals	198	217.6					+0.400
Between treatments	1	64.3	64.3	82.68	3.89	6.76	
Within treatments	(197)	153.2	0.8				+0.596

Adjusted mean for weight of sprouts per tuber control = 3.16; and treated = 1.25; with a difference of 1.91.

Minimum difference required for significance between adjusted means of weights of sprouts at the .05 level = 0.25; and at the .01 level = 0.32.

TABLE 5— *Analysis of covariance of the effect of 2,4-D treatment on the number of sprouts per tuber (y) and the tuber weight in grams (x) in Red McClure potatoes. Field test samples.*

Variability due to	D/F	Sums of Squares and Products			Variance Analyses			
		x^2	xy	y^2	x Obs. F	Req. F .05	Req. F .01	y Obs. F
Totals	199	611372.6	15528.6	817.0				
Between treatments	1	107193.8	4537.6	192.1	42.10	3.89	6.76	60.86
Within treatments	(198)	504178.8	10991.0	624.9				

Variability due to	D/F	Adjusted Sums of Squares		Obs. F	Req. F		r
		Sums of Squares	Mean Squares		.05	.01	
Totals	198	422.6					+0.695
Between treatments	1	37.3	37.3	19.05	3.89	6.76	
Within treatments	(197)	385.3	2.0				+0.619

Adjusted mean for the number of sprouts per tuber control = 4.45; and treated = 5.41 with a difference of 0.96.

Minimum difference required for significance between adjusted means of number of sprouts at .05 level = 0.39; and at .01 level = 0.51.

Effect of Treatment on Second Year Yields

All replications of the treated and the control lots were harvested September 19th, 1950. An analysis of variance indicated no significant difference in total yield.

Summary

1. The intensified red skin color of Red McClure potatoes, produced by treating growing plants with the sodium salt of 2,4-D at rates of ⅓ and 1 pound per acre, persisted throughout a 6-month storage period.
2. Treatment produced potatoes with a significantly lower average weight of sprouts and with significantly more sprouts than the controls.
3. When treated and control tubers were desprouted and planted, there were no significant differences in neither stand, number of stems per plant nor yield.

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THE COMMONWEALTH POTATO COLLECTION

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The Commonwealth Potato Collection, which today numbers some 2,500 lines of indigenous American potato species and varieties, had its origin in a visit paid by the Director of the then Imperial Bureau of Plant Breeding and Genetics, Dr. P. S. Hudson, to India in 1936, during which the possibilities of a new potato breeding program in that country were discussed.

The classic Russian expeditions organized by Professor N. I. Vavilov, which were sent all over the world in search of new varieties of food plants for improving the cultivated plants of the U.S.S.R., served as a basis in the planning of a British potato collecting expedition to the original home of the potato, South America. From the beginning it was considered that the British expedition should be organized by the then Imperial Agricultural Bureaux (later, Commonwealth Agricultural Bureaux) with funds contributed from all those countries in the British Empire and Dominion, which, in addition to India, had become interested in the scheme. No definite date for the expedition was set. In 1937 an expedition, with funds from the Percy Sladen Trust, was planned to study the natural history of the Lake Titicaca region of Peru and Bolivia. The possibility was thus presented of sending Imperial Agricultural Bureau collectors to the same region with the Percy Sladen expedition. Unfortunately, this plan was not feasible, as Dr. Hudson, who planned to do the collecting, had to postpone his trip for health reasons, and in the end had to give up all hope of being able to carry it out.

Finally, the Imperial Agricultural Bureaux expedition went out to South America in December 1938, arriving in January 1939. It was led by Mr. E. K. Balls — a professional plant collector and amateur botanist of some renown, with the present writer as potato specialist. E. K. Balls also made a small collection of approximately 50 lines of wild potatoes in Mexico in 1938 where he was engaged in obtaining ornamental plants for acclimatization in England.

By 1939 the scope of the expedition had been widened greatly, and from a small-scale collecting trip in the Lake Titicaca basin it had been extended to include the whole of the Andes range from North Argentine through Bolivia, Peru and Ecuador to Colombia. The plan was to send all the collected material to the Potato Virus Research Station at Cambridge, England, where it would be grown and multiplied under the supervision of the Director, Dr. R. N. Salaman, and all material suspected of serious diseases discarded immediately. It would then be distributed

to the contributing Empire countries, after which no central collection would be retained in England, except for the portion of it that had already been distributed to breeders in the British Isles. As we shall see later, this plan had to be modified considerably.

The scientific planning of the expedition was such an important part of it that it will perhaps not be amiss to go into a few details at this point before dealing with the expedition itself.

It was found necessary to make a detailed study of the literature of the Russian expeditions in 1925-1932, as also that of the German one in 1931 and the American one of Macmillan and Erlanson in 1933. In addition, the present writer made a study visit to Russia in 1938 for three weeks to investigate the details and the results of the Soviet expeditions. Attention was paid especially to the taxonomic work that had been in progress and the most promising varieties that were being studied. Furthermore, a detailed survey was made in England of the descriptions and herbarium specimens of wild potato species, most of which had been known only as preserved material and few of which had been previously studied in the living state. With the data on the times of flowering and tuberization of the wild potatoes and the considerable amount of information obtained from the Russians on the cultivated ones it was possible to map out a provisional route plan. With the funds available it was, of course, impossible to study all the regions where wild potatoes had been collected, since these occurred in every country in the New World with the exception of Alaska, Canada, British Honduras, the Carribean Island and the Guianas. The expedition was planned to concentrate on the regions where the indigenous cultivated potatoes are to be found, though even then time and money were not available to take in Chile and Venezuela.

The expedition arrived in Peru in January and was terminated in Columbia at the end of August, 1939, a few days before the outbreak of the second world war. Luckily, it had been possible to finish everything necessary by the time the war broke out. In all, the members of the expedition traveled some 9,000 miles in South America alone, using nearly every known means of transport. Of some 1,210 odd samples collected, 42 were obtained in North Argentine, 359 in Bolivia, 478 in Peru, 125 in Ecuador and 160 in Colombia (with a further 46 collected in Mexico in 1938). Potatoes were collected chiefly from markets, but trips were made also into the fields to appreciate the characteristics of the growing plants and obtain some idea of their specific identity wherever possible. Excursions were also made to the localities of the wild species in each district visited, often in the company of local botanists and agronomists, who rendered invaluable help to members of the expedition.

In October 1939 when the writer returned to England war had already broken out, but it was nevertheless decided to retain the collection and send at once as much material to the Empire countries that needed it. For the space of two years the writer worked alone, keeping the material alive and doing taxonomic and cytological work on it. From the results of this work some 5 new cultivated and 30 new wild species were described. It was further found that nearly all the previously known cultivated species and a reasonable proportion of the wild ones from the regions visited were represented in the collection.

In 1941 the decision was made by the Imperial Agricultural Bureaux not to terminate work in Cambridge, but, on the contrary, to retain the Cambridge station as a central source of supply where the material could be kept under scientific control and where a team of Empire workers could begin testing for resistance to disease and the other useful qualities that the collection was assumed to possess. In other words the work of testing the material was not to be uselessly duplicated all over the world but left to a central station, working co-operatively with the other potato breeding stations in the Empire, and from whence information and samples could be distributed when and where desired.

The organization of an Empire team of research workers was a difficult task during the war years, but little by little, in the years 1941 to 1948 a team of specialists in various subjects was assembled. The emphasis in the work carried out was always placed on "testing" and not on research, which, it was assumed, could be carried out later in whatever country was interested. Nevertheless, as will be readily seen, the dividing line between these two activities was at times rather hard to draw.

It was becoming increasingly evident in 1941-1943 that the old, rather makeshift accommodation at the Potato (now, Plant) Virus Research Station was completely inadequate. Losses through virus infection were seriously threatening the whole collection. Plans were drawn up for a new Station, specially planned to house the Potato Collection, and due to the generosity of the Nuffield Foundation the scheme was carried out in 1945 and 1946. The main part consisted of a bank of five large glasshouses, completely insect-proofed to prevent spread of viruses, and communicating with a covered corridor which in turn gave access to a set of rooms used as stores, laboratory, potting rooms, etc. The whole unit was planned throughout to serve the needs of growing special potato collections under controlled conditions, and has served as a model to similar ones in other parts of Great Britain.

During the years 1941 to 1948 the main testing work of the Station was carried out. It can be roughly grouped under the following heads:

1) *Resistance to Blight*

Work was begun by M. Petterson, continued by S. Dickinson of the Plant Breeding Institute, Cambridge, and is at present being done by M. A. Keay. Miss Keay is also working on physiological races of the fungus. Promising lines of wild species from Mexico were shown to be blight immune or highly resistant, and a few species from South America were shown to possess blight immunity. All these have been distributed to Commonwealth breeders and form the basis for the modern work on these lines.

2) *Virus Studies*

W. R. Wortley has been working on the virus content of the collection, finding that most of the viruses previously known in England were present, together with two new ones, namely, Veinal Yellows (as yet undescribed) and Veinal Necrosis (described by Silberschmidt and Nobrega in Brazil). Wortley has also started work on resistance to the Y virus and leaf-roll virus, obtaining some promising lines resistant to the former.

3) *Frost Resistance*

C. M. Driver worked on the frost resistance of the collection, confirming the results obtained by the Russians and finding other species and varieties resistant to moderate frost incidence. He subjected the young plants to a temperature of —3°C. for two hours after a preliminary cooling and obtained resistance in six cultivated and four wild species. So far, breeding work with this material has not been started in Great Britain or in Commonwealth countries.

4) *Biochemical Qualities*

C. M. Driver, K. Osancova and R. Morgensternova worked on protein and vitamin C in the collection. Although many lines showed a considerable degree of promise it was never possible to obtain enough material for the tests to make the results really worth while. Furthermore, since vitamin C is dependent on so many external factors the South American potatoes, which are not fully adapted to the environment of Great Britain, gave results which could not be interpreted without a much deeper knowledge of vitamin C in potatoes, generally. Finally, it was decided to discontinue this part of the work and for general studies in potato biochemistry to be taken over by an Agricultural Research Council unit. Work on specific gravity, giving an indication of the starch content, was carried out by A. Koppel, and various promising lines were noted.

5) *Resistance to Eelworm* (Golden Root Nematode)

Studies were carried out by C. Ellenby at Newcastle-upon-Tyne (University of Durham), who found several promising lines, above all *S. Ballsii, S. sucrense* and a few others. The first-mentioned species was susceptible to infection but did not develop cysts.

6) *Photoperiodic Response*

Investigations on a part of the collection to photoperiod by the present writer were carried out in 1940 and 1941. Most species and varieties tested were shown to be short-day adapted, though some could produce a yield, even though delayed, under normal conditions in England. Based on these results, two of the new glasshouses at the new research station had black-out blinds, so that the potatoes that needed them most could be given short 12-hour days during their period of growth. It was thought at first that these short-day adapted potatoes would be particularly suitable for breeding work in the tropics. This has not proved to be correct, however, as except at high altitudes the high tropical temperatures appear to exert a depressing effect on the yield.

7) *Cytology*

Chromosome counts were carried out by the writer, assisted by A. Koppel, on nearly a thousand lines. The polyploid series of species (2n=24, 36, 48, 60, 72.) described by the Russians was confirmed. The chromosome counts, besides giving invaluable information in the breeding work at other stations, served as a key to the studies on interspecific hybridization to be mentioned below.

8) *Preliminary Breeding Studies*

It has never been within the scope of the Cambridge station to attempt the production of the finished commercial variety, and for this reason only the initial stages of the breeding work were carried out. An important adjunct to this was the crossability survey, made by C. M. Driver, K. Shepherd, and the present writer. Valuable information was thus obtained for the use of potato breeders, on the possibility of the utilization of the different wild and cultivated species in their breeding programs.

9) *Other Observations*

Wart tests were carried out by the Ministry of Agriculture Plant Pathology Laboratory at Rothamstead. Many immune lines were encountered, but since wart immunity is already well-known in British commercial varieties this character in the South American potatoes is therefore of no practical importance.

Certain cultivated species, such as *S. Rybinii, S. Phureja, etc.*, were observed to possess an extremely short dormancy period, but since the aim of most breeders is, on the contrary, to produce varieties that sprout very slowly, the character of short dormancy has so far been of no commercial value.

Another interesting character is that of drought resistance. Many of the wild species in the collection would seem to possess resistance to drought, judging by the semi-arid conditions of their natural habitat, but so far it has been impossible to carry out any tests in this direction.

It would be very interesting if some work on these lines could be carried out in the United States, where, with the facilities at their disposal in California and elsewhere, American workers might obtain some valuable and interesting results.

Recent Work and Developments.

By the beginning of 1948, when the present writer was commissioned to Colombia to organize a potato research program for the Government of that country, the first phase of description and testing of the material was virtually complete. Nevertheless, tests have been carried out subsequent to that date by A. Charles on susceptibility to early blight (*Alternaria solani*) with some very promising preliminary results. Furthermore, Dr. Boyd, of the Scottish Seed Testing Station at Corstorphine, near Edinburgh, has found lines apparently highly resistant to *Fusarium* attack.

Summing up the results of the tests in the last 7 or 8 years it can be stated that, on the whole, the results are not so impressive as the optimistic accounts of the Russians indicated. On the other hand, as we have seen above, they are by no means negative. The indigenous cultivated species of South America have been the most disappointing, since they have not been shown to possess many valuable characters that were not already known in Britain, with the exception of resistance to virus Y and to frost.

The wild material has, however, been shown to be of great interest from the point of view of resistance to disease (blight, dry rot, virus, *etc.*) frost, eelworm, and many other characters that were completely unknown before these studies were commenced. Nevertheless, this wild material possesses very few factors for good yield, good flavor and general good agronomic characters. It must always be crossed sooner or later with cultivated potatoes, which alone can contribute these factors. Here, however, is precisely where the chief difficulty lies, for, owing to the systematic isolation of many wild potatoes from the group of the cultivated ones the wild ones are often difficult or impossible to cross with these latter. Luckily, this is not always the case, and *S. demissum,* whose varieties possess immunity to blight and resistance to frost and viruses, is fortunately readily hybridizable with *S. tuberosum*. The chief difficulty that still has to be solved is the breakdown of sterility barriers between many of the wild potatoes and their cultivated relatives so that the one or two genes for disease resistance can be introduced into the genic background of the cultivated ones. Even when this has been achieved many backcross generations to the cultivated parent are necessary before the hybrids begin to show good commercial qualities.

The second phase of the work at the Commonwealth Potato Station (as it is now called), under the newly appointed Director, Dr. K. Dodds, has

been to intensify investigations on the crossability of the species and to begin research on the inheritance of the genes conferring resistance to disease. Cytological investigations of the hybrids are also being conducted.

Large-scale testing has been reduced to a minimum and the tuber lines of the greater part of the collection, especially the cultivated species which had shown no promise in the previous tests, have been destroyed. As selfed seed of most of these had been produced by C. M. Driver and the present writer during the years 1941 to 1948, they are now kept in this form, and will be resown only after every 6 or 8 years. In this way, more time and space can be devoted to research, which otherwise would have been taken up with purely routine maintenance.

Although we have not planned to make any new collections of cultivated material in the near future, specimens of wild potatoes are still being added from time to time. The present writer has sent wild species back from Colombia, the most interesting being the diploid *S. Andreanum* which seems to be blight-immune. A collecting expedition was made to Mexico by the writer in 1949 in which about 130 samples of wild potatoes were collected, among them being nearly all the species that had previously been known only from herbarium material. In this way it is hoped to be able not only to find new sources of disease resistant potatoes, but also, by hybridizing species previously unknown in the living state, to try to break down the interspecific crossability barriers that have hitherto proved unassailable.

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NOTES ON INDUCED POLYPLOIDS IN THE TUBER-BEARING[1] *SOLANUM* SPECIES AND THEIR CROSSABILITY WITH *SOLANUM TUBEROSUM*

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Chromosome doubling was induced at this Laboratory in a few wild *Solanum* species and species hybrids with the following aims: (1). to double the chromosome number of some 24-chromosome species, possessing characters valuable from the breeding point of view, in order to cross them with *S. tuberosum* at the tetraploid level. Similar work has been done earlier by Johnstone (1939) and Livermore and Johnstone (1940). (2). to produce material with 2n=96 out of certain 48-chromosome species which do not normally cross with *S. tuberosum* readily, in order to use them in breeding. Lamm (1943) found that crosses between *S. acaule* and *S. tuberosum* can be effected easily, if the doubled plants of the former species are used as female parents. (3). to produce amphidiploids out of sterile species hybrids. *S. artificiale* produced by Toxopeus (1947) from the sterile hybrids of the cross *S. chacoense* x *S. antipoviczii* seems to be the only *Solanum* amphidiploid that has so far been produced.

Materials and Methods

The following is the list of the material used in this experiment and the breeding value of each of them.

1. *S. chacoense,* 2n=24. Some varieties of this species are known to possess resistance to the colorado beetle (Schick, 1937; Stelzner, 1943, a, and Torka, 1949) and further they are also scab immune (Reddick, 1939) Livermore and Johnstone (*l.c.*) observed that doubling increases its crossability with *S. tuberosum*.

2. *S. kesselbrenneri,* 2n=24. (Commonwealth potato collection No. 819. This species has a short rest period (Stevenson and Clark, 1937).

3. *S. rybinii,* 2n=24. (Commonwealth potato collection No. 546). Some varieties of this extremely variable species exhibit resistance to virus Y. The tubers mature early and have a short rest period (Stevenson and Clark, *l.c.*). A few F_1 plants of the cross *S. rybinii* x *S. tuberosum* that have been observed were absolutely sterile.

4. *S. polyadenium,* 2n=24. Black (1944), in studies on breeding varieties possessing blight-resistance with field immunity to viruses A and X,

1. A joint contribution of the Institute of Genetics and the Institute of Plant Breeding, Wageningen, Holland.

2. The writer is thankful to the United Nations Educational, Scientific and Cultural Organization for the award of a Fellowship during the course of this study.

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reports that *S. polyadenium*, which is blight immune and is very repulsive to green flies, showed greater disease-resistant properties than any other potato species. According to Stelzner (1949), the doubled plants of *S. polyadenium* can be readily crossed with *S. tuberosum*, the resulting hybrids being resistant to the colorado beetle, *Phytophthora* and Y virus.

5. *S. acaule*, 2n=48. This is a valuable species owing to its high frost resistance, though not much breeding work in this direction has been done and no results of any practical value seem to have been obtained so far. The variety Recoba and the hybrids of the reciprocal cross Recoba x Bukasov were used for doubling purposes. Stelzner (1943,b) has suggested that it will be worthwhile to use inter-varietal hybrids of this species in breeding.

6. *S. longipedicellatum*, 2n=48. (Commonwealth potato collection No. 28). This species has been found to be resistant to a series of *Phytophthora* biotypes isolated in Holland (Toxopeus, unpublished), but crosses with *S. tuberosum* have not been successful so far.

7. F_1 *S. macolae* x *S. simplicifolium*, 2n=24. *S. macolae* is resistant to the colorado beetle (Stelzner and Torka, 1948) but crosses with *S. tuberosum* were unsuccessful. However it crossed readily with another 24-chromosome species, *S. simplicifolium* and at the time this experiment was started it was not known whether the F_1 hybrid was fertile or not. Even if the F_1 was fertile, it was considered desirable to produce the amphidiploid so that they can be crossed with *S. tuberosum* at the same chromosome number level also.

8. F_1 *S. acaule* x *S. simplicifolium*, 2n=36. It became necessary to produce the amphidiploid, as the normal F_1 had been found to be totally sterile.

The techniques employed in this experiment have been described in detail elsewhere (Der Züchter) and hence will only be briefly mentioned here. Of all the different colchicine treatment methods tested, the colchicine-agar seed treatment proved to be very successful, the percentage of doubled plants obtained varying from 20 to 50 in the different material. The outline of the method is as follows: Seeds are germinated in sterilized petri dishes on an colchicine-agar jelly comprised of equal parts of 0.5 per cent colchicine and 2 per cent agar at ± 12°C. Soon after germination, when the root tips are 3 to 4 mm. long, the young plants are washed thoroughly in water and transferred to another petri dish with moist filter paper. When the first leaves appear, the plantlets are transplanted into soil.

The doubled plants were generally recognized by a study of characters like general growth habits, leaf thickness and length-breadth index, stomatal size and frequency, pollen size and fertility *etc.* In many cases the polyploid condition has been confirmed by chromosome counts in leaf tissues as only chromosome counts provide the final criteria of the

doubled condition. Leaf smears were made by the following schedule (Prakken and Swaminathan, 1950) evolved from Tjio and Levan's (1950) and Gerstel's (1949) techniques. The method is also applicable to root tissues. Root tips or growing young leaves are treated with 0.002 M per 1 (0.27 g/l) solution of 8-hydroxyquinoline for 3 to 4 hours and then fixed and macerated in a warm (60°C) 1/10 dilution of concentrated hydrochloric acid for 10 minutes. They are washed well in water, placed in a staining dish containing 2 per cent acetic orcein for 5 minutes and finally smeared. This method proved satisfactory to determine the chromosome numbers in leaf as well as root tissues in all the *Solanum* material studied and thus provided a rapid device to control the chromosome numbers of the material under study at an early stage in the investigation.

Experimental Results

(a) General Features of the Polyploids.

A part of the doubled material was grown in the green house for hybridization work and the rest in the field for general observation and cytological studies. Although in most cases there were not any appreciable differences in the general growth and vigor between the doubled and undoubled material in the green house, the polyploids were comparatively poorer in growth under field conditions. All the doubled plants were about ten to fifteen days late in commencing flowering in relation to the controls, possessed thicker leaves with more prominent hairs, showed a lower leaf length-breadth index and had larger stomata. (Table1). The flowers were larger in size, calyx more hairy, pedicels thicker and the anthers thicker but shorter. Figures 1 to 6 depict photographs of some of the doubled plants and their leaves.

(b). Pollen Size and Fertility.

The size of the pollen grains, number of germ pores per pollen grain and the average pollen fertility percentages (percentage of stainable pollen) in relation to polyploidy are presented in table 2. From the fertility percentages the following points emerge (1) Among the doubled plants of the 2n=24 species, the fertility percentages were low in *S. chacoense, S. kesselbrenneri,* and *S. rybinii* which are predominantly allogamous species, in comparison with *S. polyadenium* which is a completely self-fertile species. However, while all the doubled plants of *S. polyadenium* showed nearly the same pollen fertility there were great inter-plant differences in the other three species. Thus, in *S. kesselbrenneri* there occurred among the doubled plants a few with nearly 60 per cent stainable pollen and several showing no more than 10 per cent. Such differences are also apparent from the fact that the doubled *S. chacoense* plants, produced by Livermore and Johnstone (1940), showed only 10 per cent normal pollen grains

TABLE 1—*Leaf characters*

Species	Chromosome Numbers	Leaflet length - breadth Index Mean ± S.E.	Thickness of Leaves in mm. Mean ± S.E.	Size of Stomata in Microns
1. *S. chacoense*	24 48	2.65 ± 0.036 1.50 ± 0.033	0.269 ± 0.011 0.350 ± 0.015	30.6 ± 0.73 43.2 ± 0.89
2. *S. kesselbrenneri*	24 48	1.61 ± 0.054 1.15 ± 0.061	0.416 ± 0.016 0.570 ± 0.010	33.2 ± 1.54 42.3 ± 2.25
3. *S. polyadenium*	24 48	2.19 ± 0.041 1.51 ± 0.039	0.398 ± 0.018 0.509 ± 0.018	23.3 ± 0.65 33.1 ± 0.71
4. *S. rybinii*	24 48	1.89 ± 0.075 1.46 ± 0.062	0.300 ± 0.010 0.439 ± 0.065	26.5 ± 0.91 46.6 ± 1.12
5. *S. longipedicellatum*	48 96	1.79 ± 0.032 1.13 ± 0.038	0.336 ± 0.016 0.473 ± 0.024	29.8 ± 0.91 37.6 ± 0.86
6. *S. acaule*	48 96	1.43 ± 0.041 1.14 ± 0.039	0.372 ± 0.018 0.452 ± 0.012	29.9 ± 0.33 43.2 ± 0.68
7. F_1 *S. macolae* x *S. simplicifolium*	24 48	1.78 ± 0.051 1.32 ± 0.049	0.317 ± 0.013 0.402 ± 0.018	24.6 ± 0.32 34.3 ± 0.71
8. F_1 *S. acaule* x *S. simplicifolium*	36 72	1.39 ± 0.038 1.16 ± 0.033	0.410 ± 0.021 0.518 ± 0.018	33.4 ± 1.21 42.9 ± 0.64

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- **Where else but in Maine can you buy a <u>wider selection</u> of potato varieties grown on the Eastern Seaboard?**

Answers to the above questions all point to

Fig. 1. *S. chacoense.*
1. Control (2n=24). 2. Doubled (2n=48).

Fig. 2. *S. longipedicellatum*
1. Control (2n=48). 2. Doubled (2n=96).

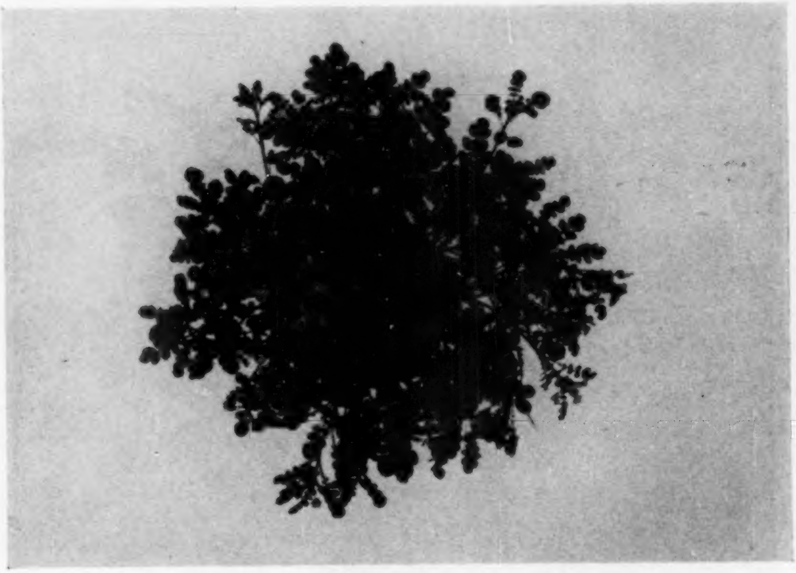

Fig. 3, a. Control plant of *S. acaule* Recoba (2n=48).

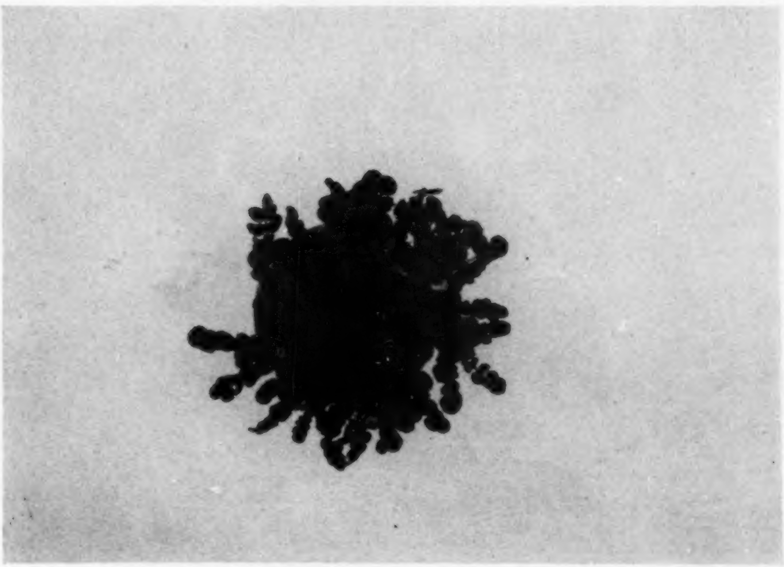

Fig. 3, b. Doubled *S. acaule* (2n=96).

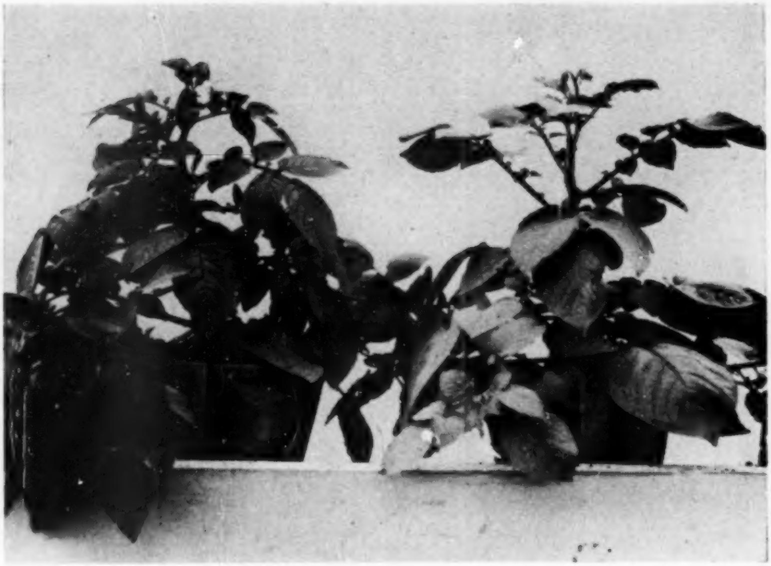

Fig. 4. F_1 *S. macolae* x *S. simplicifolium*.
1. Control (2n=24). 2. Amphidiploid (2n=48).

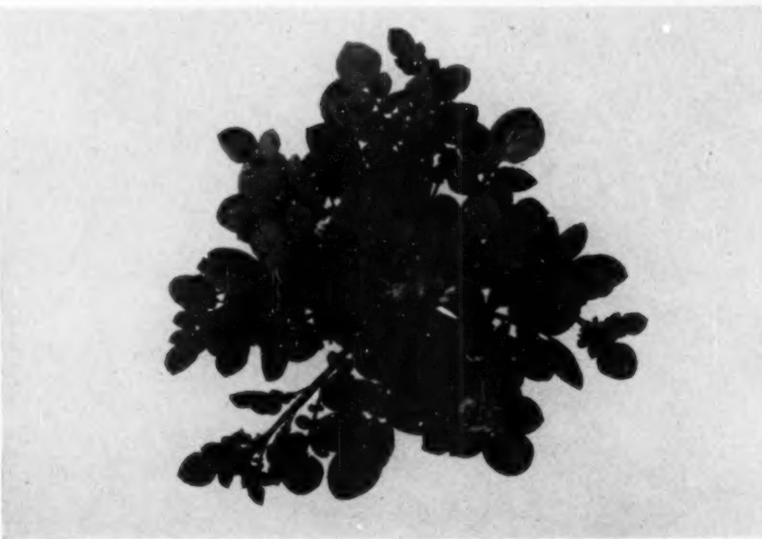

Fig. 5. F_1 *S. acaule* x *S. simplicifolium*. Amphidiploid (2n=72).

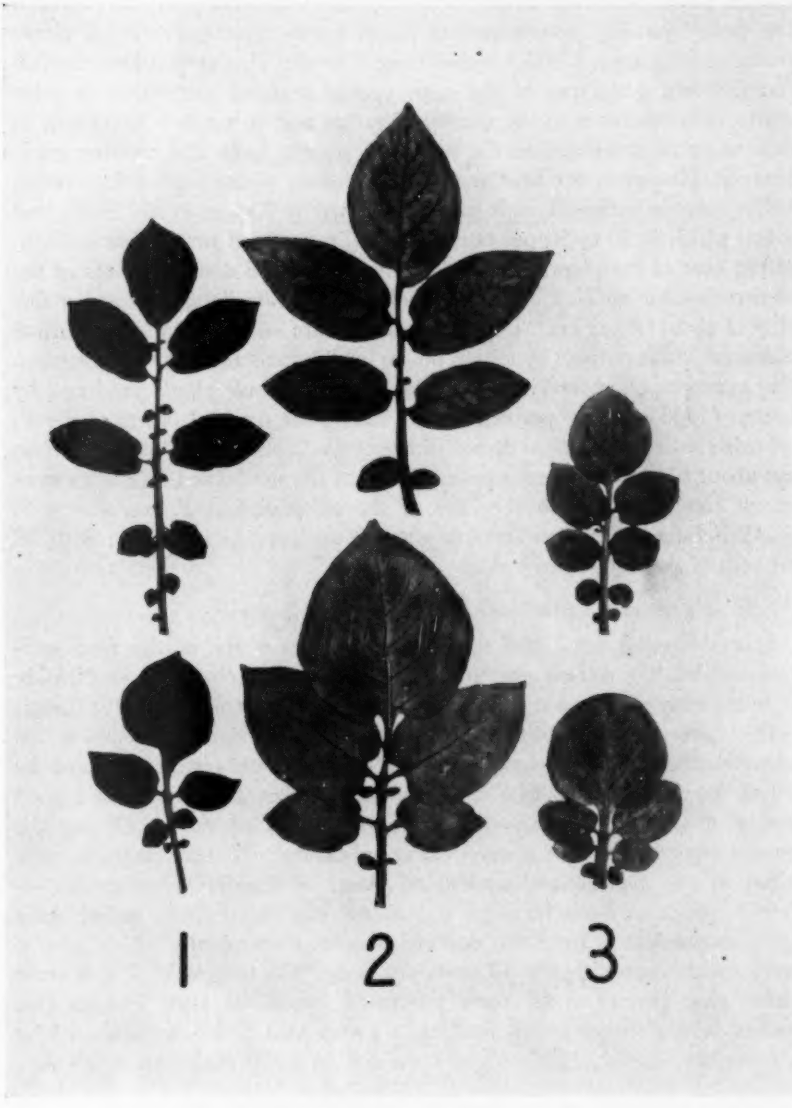

Fig. 6. Leaves of control (top) and doubled (bottom) plants of
1. *S. longipedicellatum.*
2. F_1 *S. macolae* x *S. simplicifolium.*
3. F_1 *S. acaule* x *S. simplicifolium.*

and the plants produced during this experiment approximately 50 per cent. The pollen fertility percentages of the 6 autotetraploid *S. rybinii* plants produced by Lamm (1945) varied from 0 to 45. This emphasizes the fact that different genotypes of the same species respond differently to polyploidy with reference to the quality of pollen and hence it is important in such work to transfer into the polyploid state a large and varying genic material. However, for breeding purposes, even plants with a low pollen fertility can be sufficient, as it has been shown by Krantz *et al* (1939) that pollen which is 20 to 50 per cent stainable, cause seed production in 76 to 94 per cent of the plants of *S. tuberosum*. (2). The doubled plants of the 48-chromosome species, *S. acaule* and *S. longipedicellatum* showed a fertility of about 68 per cent. Both these species are self-fertile and the normal plants are characterized by a high pollen fertility and abundant fruit setting. The average pollen fertility of the doubled *SS. acaule* plants produced by Lamm (1943) was 66 per cent. (3). Among the doubled plants of the F_1 hybrids studied, the amphidiploid of the cross *S. acaule* x *S. simplicifolium* had about 61 per cent fertile pollen, whereas the undoubled F_1 plants were almost totally sterile. In the case of the amphidiploid *S. macolae* x *S. simplicifolium,* the pollen fertility was 69 per cent as compared with 85 per cent of the undoubled plants.

(c). Effect of Chromosome Doubling on Self-sterility.

Several investigators have studied the problem of the change from self-incompatibility to self-compatibility accompanying the change from diploidy to tetraploidy in various genra (cf. Stout and Chandler, 1941; Lewis 1943). Livermore and Johnstone (1940) who studied this problem in the tuber-bearing *Solanums* found that although no seeds were obtained by selfing the normal plants of *S. bulbocastanum,* about 25 berries with a good supply of seed were obtained by selfing the doubled plants. During the present experiment, 5 clusters with approximately 10 buds in each were selfed in the doubled and undoubled plants of the following species — *S. chacoense, S. kesselbrenneri* and *S. rybinii.* From these, selfed seeds were obtained only from the doubled *S. chacoense* plants, which gave 6 berries with approximately 40 seeds per berry. The tetraploid *S. chacoense* plants gave berries under open pollinated conditions also. Though this species belong to the group Stellata, a group said to be characterized by self-sterility, Torka (1949) found some self-fertile *S. chacoense* types also.

(d). Crossability of the Artificial Polyploids with S. tuberosum.

The chief aim of this experiment was to try to overcome certain difficulties normally met with while utilizing the species used in this study in practical breeding. In accordance with this objective, a large number of reciprocal crosses were carried out between different varieties of the

TABLE 2—*Pollen characters*

Species	Chromosome Number	Mean Pollen Fertility (Per Cent)	Pollen Diameter in Microns Mean ± S. E.	No. of Germ Pores in Pollen
1. *S. chacoense*	24	95	16.5 ± 0.12	3
	48	49.5	23.1 ± 0.25	4
2. *S. kesselbrenneri*	24	90 to 100	16.5 ± 0.31	3
	48	35.3	26.4 ± 0.25	4
3. *S. polyadenium*	24	99	14.4 ± 0.15	3
	48	69.5	21.1 ± 0.36	4
4. *S. rybinii*	24	90 to 100	17.8 ± 0.40	3
	48	33.9	26.4 ± 0.25	4
5. *S. longipedicellataum*	48	99	20.1 ± 0.15	3
	96	68	30.8 ± 0.52	4
6. *S. acaule*	48	99	21.8 ± 0.33	3
	96	69.5	29.7 ± 0.59	4
7. F_1 *S. macolae* x *simplicifolium*	24	85	16.6 ± 0.23	3
	48	69	26.5 ± 0.27	4
8. F_1 *S. acaule* x *S. simplicifolium*	36	0 to 2	—	—
	72	61	29.8 ± 0.46	4

common potato and the doubled material. Crosses with *S. tuberosum* as the pistillate parent were performed at the green house of the Institute of Plant Breeding, Wageningen, on plants that had been grafted on tomato. The crosses involving the doubled material as mother parents were carried out at the green house of the Institute of Genetics, where because of the lack of a thermostat control the temperature prevailing during most of the pollination period was rather high (25 to 30°C). However, the humidity was kept as high as possible by wetting down the floor, benches and walls now and then and moreover, the pedicels were sprayed a few times with a 25 mg/l solution of a-naphthalene acetic acid. The following varieties of *S. tuberosum* were used as pollen parents: Alpha, Ackersegen, Eigenheimer, Katahdin, Libertas and some new selections of the Plant Breeding Institute namely I.v.P. 354 and 920. Bintje, I.v.P. 920 and the American varieties 96-56 and Houma were used as mother parents. In all cases, a few crosses were also performed with the control plants of the material used for doubling but no attempt was made to compare the relative crossability of the doubled and undoubled plants with *S. tuberosum,* as from the practical point of view, it is not the number of successful crosses but only the number of fertile hybrids obtained that is important. Table 3 gives the results of the hybridization work and its chief features are summarized below.

1. *S. chacoense.* The doubled plants can be crossed with *S. tuberosum* reciprocally. The percentage of successful crosses was higher when *S. tuberosum* was used as the mother parent but this may be due to the effect of the higher temperature that prevailed in the green house where the reciprocal crosses were done. Livermore and Johnstone (1940) found that doubling increased the crossability of *S. chacoense* with *S. tuberosum.*

2. *S. kesselbrenneri.* Hybridization between the doubled plants of this species and the cultivated varieties succeeded reciprocally.

3. *S. rybinii.* Reciprocal crosses with *S. tuberosum* were successful.

4. *S. polyadenium.* The crosses were successful only when *S. tuberosum* was used as the mother parent. Stelzner's (1949) results were also the same.

5. *S. acaule.* With the doubled plants of *S. acaule* and the mother parents, it is very easy to effect crossings with *S. tuberosum.* In this connection, it is interesting that a reversal of this method — namely crossing doubled *S. tuberosum* (mother parent) with normal *S. acaule* — was found to be unfruitful by Stelzner (1941).

6. *S. longipedicellatum.* Crosses between the doubled plants of this species and *S. tuberosum* succeeded readily although with the undoubled plants have not given any fruit setting so far. The behavior seems to be analogous to that of *S. acaule.*

TABLE 3—*Crossability of the induced polyploids with S. tuberosum.*

Cross	No. of Flowers Pollinated	No. of Berries Obtained	Average No. of Seeds per Berry
1. a. *S. chacoense* (2n=48) x *S. tuberosum*	116	8	32
b. Reciprocal	36	4	71
2. a. *S. kesselbrenneri* (2n=48) x *S. tuberosum*	24	2	26
b. Reciprocal	28	5	30
3. a. *S. rybinii* (2n=48) x *S. tuberosum*	21	4	23
b. Reciprocal	32	3	45
4. a. *S. polyadenium* (2n=48) x *S. tuberosum*	63	—	—
b. Reciprocal	38	3	27
5. a. *S. acaule* (2n=96) x *S. tuberosum*	86	32	31
b. Reciprocal	49	—	—
6. a. *S. longipedicellatum* (2n=96) x *S. tuberosum*	8	2	34
b. Reciprocal	24	—	—
7. a. F_1 (*S. macolae* x *S. simplicifolium*) (2n=48) x *S. tuberosum*	33	6	34
b. Reciprocal	42	16	104
8. a. F_1 (*S. acaule* x *S. simplicifolium*) (2n=72) x *S. tuberosum*	121	33	78
b. Reciprocal	43	—	—

7. F_1 *S. macolae* x *S. simplicifolium*. The amphidiploid crosses easily with *S. tuberosum* reciprocally. In crosses with the undoubled F_1, a few berries were formed but no seeds could be obtained.

8. F_1 *S. acaule* x *S. simplicifolium*. Crosses between the amphidiploid and *S. tuberosum* can be performed, if the former is used as the mother parent. The undoubled F_1 is totally sterile and no crosses can be performed with it.

The meiotic behavior of the polyploids has been studied and will be published elsewhere.

Discussion

Potato breeders engaged in inter-specific hybridization have often met with problems of incompatibility (self and cross) and in a few cases it has been found that the incompatibility may be overcome by doubling the chromosome number of one of the parents (cf. Livermore and Johnstone, 1940; Lamm, 1943 and Stelzner, 1949). Further, unreduced gametes are sometimes regularly functioning and thus fertile hybrids occasionally result from 2x X 4x crosses even without artificially inducing chromosome doubling in the 2x parent (Propach, 1938; Stelzner, 1943 a; Ivanov, 1939; Ivanovskaja, 1941 and Prakken and Swaminathan, unpublished). The results of the hybridization work presented in this paper show that although the doubled *S. chacoense*, *S. kesselbrenneri* and *S. rybinii* can be crossed with *S. tuberosum* reciprocally without any difficulty, the cross between the doubled *S. polyadenium* and normal *S. tuberosum* could be effected only with the latter as the mother parent. Stelzner's (1949) experience was also the same and here seems to be an instance of total incompatibility being converted into an one-way one, on chromosome doubling.

With reference to the 48-chromosome species used in this experiment, the doubled *S. acaule* and *S. longipedicellatum* plants were very vigorous, fertile and showed a good fruit setting both after crossing and under open-pollinated conditions. Thus, the condition is the opposite of that reported by Johnstone (1939) in *S. andigenum* and *S. tuberosum*. In both these species, the doubled plants were dwarfed, thick-stemmed, very succulent, infertile and deformed in various ways when compared with the diploid checks, thus suggesting that these species may be tetraploids already. Inasmuch as true species seem to suffer more than species-hybrids when converted into the polyploid state, it is likely, judging purely from the growth and fertility characters of the induced polyploids, that *S. acaule* and *S. longipedicellatum* might have had a hybrid origin. From the breeding point of view, both these species behave in the same manner — they are difficult to be crossed with *S. tuberosum* normally but it is very easy to effect the hybridization with the doubled plants as the mother parents. *S.*

longipedicellatum does not seem to have been used in breeding so far and the hybrids from the cross between it and the potato varieties may be of great practical importance in view of the high *Phytophthora*-resistance possessed by this species.

Crossing two wild species possessing desirable features first and then hybridizing the ensuing progeny with *S. tuberosum* may sometimes prove useful in breeding work (Toxopeus, 1947), involving as it does a principle analogous to the one suggested by Reddick (1943) for the production of varieties possessing both scab-resistance and blight immunity. Black (1943) outlined a method of producing fertile blight-resistant hybrids between *S. demissum* and *S. tuberosum* making use of a 'bridge' species *S. rybinii.* A cross was made between *S. demissum* (2n=72) and *S. rybinii* (2n=24) and from this one seedling was produced with 48 chromosomes. This plant was then crossed with *S. tuberosum,* the triple hybrids thus produced being perfectly fertile. Among the triple hybrids reported in this paper (the F_1 progeny has not yet been studied), it is likely that those between the amphidiploid *(S. macolae* x *S. simplicifolium)* (2n=48) and *S. tuberosum* may be fertile whereas it is not possible to say what the nature of the hybrid of the cross amphidiploid *(S. acaule* x *S. simplicifolium)* x *S. tuberosum* will be, which should have a chromosome number of 2n=60, judging from the regular meiotic behavior of the amphidiploid. Not much breeding work has been done with *S. acaule* so far and according to Black and Driver (1947) the best result obtained in Germany with this species was a seedling selected in the fourth backcross generation which was capable of resisting 2 to 3°C of frost for a short period but which succumbed when that temperature was sustained.

An interesting feature of the cross *S. macolae* x *S. simplicifolium* is that, though taxonomically these two species are only remotely related, the F_1 hybrid between them is fertile and the meiosis is very regular. Propach (1940), who studied a large number of inter-specific hybrids in the 24 chromosome species cytologically, concluded that the chromosomes of these species are not structurally differentiated in view of the fact that if it becomes possible to obtain flowering hybrids between any two diploid species, meiosis is found to be very regular, however remote the taxonomic affinities between these species might be. This view, that the chromosome differentiation in the tuberous *Solanums* is not sufficient to affect pairing in species hybrids, is further borne out by Thomas's (1945) and the writer's (unpublished) observations. If this holds good for all the species of the section Tuberarium, it will imply that if species hybridization is planned in such a way as to result in 48 chromosome hybrids, which can be expected to be fertile and show regular meiosis, these can be crossed or backcrossed to *S. tuberosum* without the occurrence of meiotic irregularities in the resulting hybrids and consequently without the risk of losing chromosomes

having some of the desirable genes in a part of the progeny. The fact that Thomas (l.c) found meiosis to be regular in the triple hybrids of the cross F_1 *(S. demissum* x *S. rybinii)* x *S. tuberosum* lends support to this hypothesis and seen in this light, Black's (1943) method of crossing *S. demissum* first with *S. rybinii* and then crossing the hybrids with *S. tuberosum* has much to commend it. It, thus, seems advisable to base the breeding program with the wild *Solanums* on the maintenance of the 48 chromosome number level in the hybrids.

Summary

The growth habits, morphological characters and fertility features of the colchicine-induced polyploids of the following species have been described: *S. chaçoense, S. kesselbrenneri, S. rybinii, S. polyadenium, S. acaule, S. longipedicellatum,* F_1 *S. macolae* x *S. simplicifolium* and F_1 *S. acaule* x *S. simplicifolium*. The crossability of the polyploids with *S. tuberosum* is indicated and the hybridization results are briefly discussed. The desirability of planning species hybridization in the tuberous *Solanums* in such a way as to maintain the chromosome number 48 in the hybrids is stressed.

Dr. H. J. Toxopeus of the Institute of Plant Breeding, Wageningen, kindly placed at the disposal of the writer the material required for this study. To him and Prof. Dr. R. Prakken of the Institute of Genetics, the writer's thanks are due for suggestions and facilities provided for this investigation.

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DR. EARLE V. HARDENBURG HONORED BY THE POTATO ASSOCIATION OF AMERICA

Dr. Earle V. Hardenburg, Professor of Vegetable Crops at Cornell University, was elected an honorary life member of the Potato Association of America at its annual meeting in Memphis on December 2, 1950. After having served the potato industry of America so well for so many years this is an honor he justly deserved. The Association was fortunate indeed to have him as one of its active members of such long standing.

Dr. Hardenburg was born in Brocton, N. Y. and graduated from Cornell University in 1912. His Master of Science and Doctorate degrees were also conferred by Cornell University at which place he remained conducting research and teaching in the Department of Agronomy and later in the Department of Vegetable Crops. During this period he studied many phases of the potato industry and published numerous papers and bulletins on the project of potatoes. He was especially well known for his work with and knowledge of varieties, seed handling and various cultural studies.

To the growers of New York State he probably is best known for his many years of productive and instructive work on extension. He was especially outstanding in his appreciation of the growers' problems and his excellent, thorough and understanding manner of clarifying the solution of these problems for the grower. Several generations of students at Cornell University obtained their formal training with potato problems in the course taught by Dr. Hardenburg.

He was active for many years in the Potato Association of America and presented numerous papers at the annual meetings. He was President of the Association in 1921, treasurer in 1927 and also served as associate editor for a time.

He has written an authoritative book on "Bean Culture", and although he was not in good health, during that period he completed his excellent work on "Potato Production" in 1949.

It is with great sorrow and regret that I did not return to Ithaca from the Memphis meetings in time to notify Dr. Hardenburg of the action taken by the members of the Association at its annual meeting for he passed away at his home on the evening of December 4, 1950. Members of the Potato Association of America regret deeply that his kindly help and services and his association with us had to be terminated at this time.

Ora Smith

ANDREW ROBBIE HONORED

Mr. Andrew Robbie now residing at Cavalier, North Dakota, was born in Scotland, September 6, 1868. He came to this country in 1887 and spent the next year doing contract work in the construction of the Great Northern Railway westward. After a short time he entered the flour milling business at Cavalier. In 1913 he became interested in the benefits farmers could get by including potatoes in their rotations. He built a potato warehouse that year to facilitate such efforts. In 1916 he actively started farming, particularly the growing of potatoes. In 1920 he started to grow certified seed potatoes and has been growing them enthusiastically ever since. During all these years he has never spared any effort or expense in the production of good crops of high classed seed. He has been a leader in the adoption of any new practices which would accomplish the best results. Never has he refused to assist with money and effort of any experimental project. Not only has he carefully selected and guarded his foundation seed sources but has been a leader in experimentation in the use of fertilizers, sprays and vine killers. As a result he has been outstanding in both yield and quality of seed stocks. Although Mr. Robbie has been growing from 300 to 500 acres with yields varying from 300 to 500 bushels per acre, he has often run short of seed to supply his faithful customers throughout the country.

He was also a leader in the washing and shipping of high classed table stock. His "Cavalier" brand very often tops the table market. Although Mr. Robbie is approaching 83 years of age he is still a progressive and enthusiastic seed potato grower! His many friends will be delighted to learn that he has been honored with a life membership to the Potato Association of America.—R. C. Hastings

DONALD REDDICK RETIRES

Dr. Donald Reddick, who developed several varieties of blight resistant potatoes now widely grown in the United States, Central America, and South America, will retire from the Cornell University faculty December 31.

He has been at Cornell since 1905, received his Ph.D in 1909 and was appointed professor of plant pathology in 1911.

More than 30 years ago Dr. Reddick began a search for a potato resistant to blight, a costly disease for growers to control. In 1928 he discovered that a wild potato from Mexico was immune from blight and was usable in a breeding program. This wild potato is now used by scientists wherever potato varieties resistant from the late blight disease are produced.

In 1930 Dr. Reddick went on a plant exploration expedition to the mountains of Mexico and dug five or six different species of wild potatoes from 70 different places. These potatoes were brought back to the Agricultural Experiment Station at Cornell and crossed with domestic varieties. From the thousands of hybrids grown, about a dozen combined blight resistance with good market qualities and are now produced commercially. The most popular of them, Essex, was released in 1947 and is grown on thousands of acres in the United States, England, and New Zealand.

Dr. Reddick has also made notable contributions to the prevention and control of other potato diseases including scab, rugose mosaic, ring rot, and leafroll.

The Empire State Potato Club, the Potato Association of America and the Canadian Phytopathological Society have honored Dr. Reddick for his work.

He has written many articles and bulletins on fruit and vegetable disease problems and his studies on black rot of grapes have remained the outstanding work on this disease for more than 40 years. He is also credited with beginning the development of modern methods for the laboratory analysis of new fungicides.

Among his first duties at Cornell were to organize and present a formal course in Principles of Plant Disease Control and to teach mycology and methods in plant pathology to graduate students.

"Dr. Reddick took an active part in developing the department of plant pathology and bringing the subject to its present recognized position among the biological sciences through his own research work and by his supervision and training of numerous graduate students," according to Dr. G. C. Kent, head of the department.

In 1917 he discontinued teaching and began the work he likes best — personal research on fundamental problems in plant pathology. He started his extensive studies with bean diseases in 1916 and with potato blight in 1919.

Dr. Reddick was active in founding the American Phytopathological Society and was one of its first presidents. He also helped start two journals: Phytopathology, serving as manager and editor and Botanical Abstracts serving as general manager and editor for plant pathology. He is a past vice-president of the International Union of Biological Sciences and for 12 years was president of the section for pathology. He is also a fellow of the American Association for the Advancement of Science, a corresponding member of Nederlandsch Botanische Vereeniging, a life member of the Societe Linneenne de Dyon, and a member of the Society of American Naturalists, American Association of University Professors, Gamma Alpha and Sigma Xi.

Earle Volcart Hardenburg

Earle Volcart Hardenburg, Professor of Vegetable Crops at Cornell University, died suddenly at Ithaca, December 4, 1950. He had devoted his lifetime to the production and marketing of potatoes and other field-grown vegetables. Though he had suffered from heart trouble for several years, he was at his office the day of his death conducting his usual duties.

Dr. Hardenburg was born in Chautauqua County in 1889. He was farm-reared and received his bachelor of science degree in 1912 and his doctor's degree in 1919, both from Cornell. Barring leaves of absences, his entire service was in the College of Agriculture at Ithaca. He was extension project leader for his department, taught a vegetable crops course which dealt primarily with potatoes, dry beans and canning crops, and conducted research dealing with potatoes and dry beans. His course grew each year, until a hundred or more students were taking it on a purely elective basis. Quiet and unassuming in manner, Hardenburg was one of the best informed potato men in the country. He had visited many of the important potato areas and knew their problems well. Growers looked to him for guidance and loved him as a friend.

Dr. Hardenburg was secretary of the old New York State Potato Association and an organizer of the Empire State Potato Club in 1928. He had served as president of the Potato Association of America. Author of many scientific and popular papers, his books include "Potato Production" (1949) and "Bean Culture" (1927). He was a joint author of "Land for the Family" (1947). His writings were brief, clear-cut and thoroughly informative.

Dr. Hardenburg was a member of many scientific societies, was active in Masonry and served in many capacities in his church, to which he was warmly devoted. He was elected to honorary life membership in the Potato Association of America on December 2, 1950.

He is survived by his wife, Aline Crandall, and five children, one of whom, Dr. Robert Earle Hardenburg, is in marketing work with the Bureau of Plant Industry, U.S.D.A., at Beltsville.

MINUTES OF EXECUTIVE COMMITTEE MEETING, DEC. 1, 1950

Place: Hotel Peabody, Memphis, Tennessee
Presiding Officer: Reiner Bonde
Members Present: Reiner Bonde, O. D. Burke, J. C. Campbell, J. W. Scannell, and Ora Smith. H. O. Werner was asked to attend.
Members Absent: A. G. Tolaas, R. D. Pelkey, H. A. Reiley and Wm. H. Martin.

There was considerable discussion regarding the:
(1) type of membership to be encouraged in the Association,
(2) caliber of papers to appear in the Journal,
(3) change in membership dues,
(4) place and time of 1951 meeting,
(5) methods of increasing receipts of the Association.

Moved by Campbell, seconded by Scannell that the Association meet in Chicago in December, 1951. Defeated.

Moved by Burke, seconded by Campbell that the Association meet in Philadelphia in December, 1951 with the American Phytopathological Society. Passed.

Moved by Burke, seconded by Scannell that dues be increased to $4.00 per year and group subscriptions be a minimum of $1.00 annually. Passed.

Moved by Scannell, seconded by Burke that the Editor be paid the usual amount of $400.00 for his services during 1951. Passed.

Moved by Burke, seconded by Scannell that the Treasurer be paid the usual amount of $600.00 for his services for 1951. Passed.

Moved by Burke, seconded by Scannell that the President appoint a committee to study the editorial situation and policy and present a report at the next annual meeting.

Meeting adjourned.

Ora Smith, *Secretary*

MINUTES OF ANNUAL MEETING OF THE POTATO ASSOCIATION OF AMERICA

Memphis, Tenn.

DECEMBER 1, 2, 3, 1950

Dec. 2, 1950

Meeting was called to order by *Vice Pres.* Reiner Bonde in the absence of *Pres.* H. A. Reiley. A short address by H. A. Reiley was read by Dr. Bonde.

Ora Smith presented the Secretary's report which was accepted.

J. C. Campbell presented the Treasurer's report, a copy of which is attached. Report was accepted. It was called to the attention of the group that recent expenditures, particularly costs of the Journal, are mounting much higher than our income and that something must be done soon to increase our receipts.

In the absence of Dr. Martin, J. C. Campbell presented the report of the Editor of the Journal. Much difficulty has been encountered with the printers during the past year and printing costs have greatly increased. Report was accepted. The group voted their thanks to Dr. Martin and Mr. Campbell for their work during the trials of the past year's printing problems.

Report of the Certification Committee was given by Dr. Henry Darling. Report was accepted.

Report of the Potato Introduction Committee was presented by Dr. G. H. Rieman. Report was accepted.

Report of Membership Committee was presented by Marx Koehnke. Among other things, the Committee suggested that (1) the program of the annual meetings and papers in the journal be improved, (2) retain or slightly increase group subscription rates, (3) have foreign subscribers absorb a portion of the loss in exchange rates and (4) that research workers be discouraged from joining in the group subscriptions. Report was accepted.

No Resolutions Committee was appointed.

Auditing Committee of Hawkins and Koehnke presented their report which was accepted.

The Honorary Membership Committee of H. J. Evans, *Chairman,* J. C. Miller and R. C. Hastings placed the following names in nomination: Dr. E. V. Hardenburg, Andrew Robbie, Henry Talmage and Prof. J. G. Milward. Dr. Hardenburg, Cornell University, was elected on the first ballot and Andrew Robbie, Cavalier, N.D., was elected on the second ballot. Both were declared unanimously elected Honorary Life Members of the Association.

It was moved and seconded that the by-laws be changed to read "$3.00" rather than "$2.00" for annual dues. After some discussion the motion was recalled. Motion was made and seconded that the question be tabled until later in the sessions and that a report be given by the Executive Committee concerning the whole situation of members, group members and foreign members. Passed.

The Nominating Committee consisting of O. D. Burke, G. H. Starr and

TREASURER'S REPORT

Statement for the Year Ending November 30, 1950

Receipts		
Balance on Hand November 30, 1949	$2,244.77	
Annual Dues	3,452.11	
Sale of Advertising	3,279.90	
Sale of Reprints	522.45	
Miscellaneous	177.05	
Total Receipts		$9,676.28
Disbursements		
Printing of Journal (12 issues)	$6,258.17	
Printing of Reprints	462.65	
Mailing and Supplies	703.00	
Editorial Work	300.00	
Treasurer's Work	500.00	
Secretarial Work	158.40	
Miscellaneous	212.39	
Total Disbursements		$8,594.61
Bank Balance on Hand November 30, 1950		$1,081.67
Accounts Receivable		
Advertising—Sept. and Oct.	$272.87	
Reprints—Billed but not paid	89.50	
Total Accounts Receivable		$ 362.37
Bank Balance plus Accounts Receivable		$1,444.04
Accounts Payable		
Printing October Journal	856.10	
Editorial Work	100.00	
Treasurer's Work	100.00	
Total Accounts Payable		$1,056.10
Net Balance		$ 387.94

John C. Campbell, *Treasurer*

M. W. Felton presented the following slate of officers:

President — Reiner Bonde
Vice President — G. H. Rieman
Director for 3 years — Arthur Hawkins

The secretary was asked to cast a unanimous ballot for the above slate.

It was suggested that the 1951 meeting be held in December in Cincinnati in conjunction with the American Phytopathological Society.

Meeting adjourned.

Ora Smith, *Secretary*

Additional Business Session, Dec. 3, 1950.

It was moved and seconded that the by-laws be amended as follows: Under 1. "Membership and dues, A. Members," change "Two dollars ($2.00)" to read "Four dollars ($4.00)". Also under "2. American Potato Journal. C. Subscriptions and back numbers," change "$2.00 per year" to read "$4.00 per year". Carried.

It was moved, seconded and passed that the 1951 meetings be held in Cincinnati in December 1951 in connection with the meetings of the American Phytopathological Society.

Meeting adjourned.

Ora Smith, *Secretary*

Executive Committee Meeting, Dec. 3, 1950.

Moved, seconded and passed that Ora Smith be Secretary of the Association for a two-year period.

Ora Smith, *Secretary*

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